



Cloud Chamber

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TOOLS:

- [Stapler \(1\)](#)



PARTS:

- [Jar \(1\)](#)
- [Rubbing Alcohol \(1\)](#)
- [Dry ice \(1\)](#)
- [Towel \(1\)](#)
- [Flashlight \(1\)](#)
- [Basketball display case \(1\)](#)
- [Felt \(1\)](#)
[to cover the top and bottom of the chamber](#)
- [Sheet metal \(1\)](#)
[a thin square measuring 26cm a side](#)
- [Hardware cloth mesh \(1\)](#)
[same size as metal](#)
- [Aquarium cement \(1\)](#)
[one tube](#)
- [Wood screws \(1\)](#)
[4 to 6](#)

SUMMARY

Hold out your palm face up. In the time it takes you to read this sentence, two high-energy subatomic particles will likely have pierced clean through your hand.

We live in a radioactive environment and there's no escape. At sea level, the flux is roughly one particle per palm size per second, which means San Franciscans sustain an astonishing 20 million hits through their bodies each day. Denver is higher in elevation, so its protective blanket of air overhead is thinner. As a result, Mile Highers get hit at roughly twice that rate.

These particles make their presence felt by ionization — that is, ripping electrons away from their atoms. Since atomic electrons are electrically charged, they interact with all other charged particles (e.g. other electrons, protons, helium nuclei, and so on), and so any of these, when sent screaming through space, becomes a type of ionizing radiation. In addition to charged particles, some photons, such as X-rays and gamma rays, also have enough oomph to whack electrons out of their atomic orbitals and so they, too, make the list.

Much of the radiation around us comes from nuclei in the soil and the air that have too much energy to be stable; they shed their excess by expelling elementary particles. But most of the damaging corpuscles have their origins deep in outer space where pulsars, supernovae, and even stranger cosmic players accelerate elementary particles to fantastic energies and hurl them out into the cosmos. After perhaps 100,000 years of silently streaking between the stars, some of these tiny wanderers end their existence when they strike the nucleus of an atom in the air high over our heads, and explode.

Since energy and mass are two sides of the same coin, some of the enormous kinetic energy these particles often carry instantly converts into wholly new particles, sometimes thousands of them, that shower down toward Earth. Most of these new particles interact with still more atomic nuclei and quickly range out — never reaching the ground. But one exotic species, the muon, does not feel the nuclear force. As a result, muons do not get absorbed in the air. Most survive to reach Earth's surface where they fall from the sky in all directions as a steady spray of subatomic machine gun bullets that we call "cosmic rays."

Step 1 — Method #1: Build the 30-second cloud chamber.

- It turns out that these exotic particles, as well as the more mundane radiation produced by the decay of unstable nuclei near us, can be made visible inside a chamber that takes about 30 seconds to assemble if you've got some dry ice on hand. (Dry ice is easy to get from many ice warehouses or welder's supply stores. Visit <http://dryicedirectory.com> to search for dry ice dealers by area code.)
- Simply take a large jar with a metal lid and warm the jar under a flow of hot water. Then thoroughly rinse the inside with rubbing alcohol and dump out the excess. Replace the lid. Center a cake of dry ice on top of a towel. Then place the jar, lid side down, in contact with the dry ice and wrap the remaining dry ice up in the towel to prevent it from "smoking." The alcohol will evaporate from the warm sides of the jar and condense near the frigid lid.
- Do this in a darkened room. Shine a bright flashlight into the jar from the side, and you'll see pinprick-sized droplets of alcohol coalescing near the bottom. After a minute or two, when the dust inside the jar has settled out, you'll also see something extraordinary. About once a minute, just above where the droplets are forming, a ghostly line will suddenly appear and then disintegrate as falling rain of alcohol. These spectral emanations are caused by ionizing particles of radiation passing through your jar.
- These thin trails of vapor form because the ions that the passing particles leave in their wake attract the electrically neutral alcohol molecules, just like a balloon that has been electrically charged by rubbing on someone's hair readily attracts small bits of electrically neutral dander. The alcohol molecules just above where the cloud appears are almost, but not quite, cold enough to form droplets. But when a passing particle lays down a trail of ions, those ions can pull together enough alcohol molecules to entice droplets to form.
- These droplets coalesce along the track and essentially amplify its width over a trillionfold to make the particle's passage plainly visible. For obvious reasons, a radiation detector that uses tiny droplets to reveal its quarry like this is called a "cloud chamber."
- While the cloud chamber in a jar couldn't be simpler to construct, it has three drawbacks. First, it's small, so you often have to wait a long time before another cosmic ray will happen to pass through at just the right spot. Second, the curved glass makes the tracks hard to see. And finally, the show only starts after any dust particles inside have settled, and it stops as soon as the alcohol has all condensed. That limits you to just a few minutes of good viewing.
- A far better chamber would operate with a large enough volume for tracks to appear every few seconds, have flat sides for clear viewing, and would contain a reservoir of alcohol large enough to keep the show going for hours.

Step 2 — Method #2: Build the basketball case cloud chamber.



- Here's how to make a superior cloud chamber. The trick to creating cloud chambers is to find the right vessel. And nothing I've found so far trumps a basketball display case. I purchased a new one for \$30 from a local craft store, but you may need to check online or peruse your local trophy stores. These cases are clear glass on the top and three sides. The back is lined with a mirror and the bottom is covered with thin particleboard. Each side is about 26cm long.
- When the chamber is operating, tracks form within at a height of about 4cm, which makes the active volume a whopping 2,700 cubic centimeters. That is far larger than any other homemade cloud chamber I've seen, and results in a particle track every few seconds.
- First, to let the chill of the dry ice in, replace the thermally insulating particleboard on the bottom of the display case with a thin piece of conducting sheet metal. (Find a local supplier of sheet metal and have them cut it to size.) Gently push out the bottom and use the silicone cement and screws to seal your sheet metal in its place. Turn the assembly upside down and rest about 10 lbs. of books on top to insure a firm connection. Run a bead of silicone all around the inside joint to make sure the seal is airtight; air currents will destroy the tracks as fast as they form.
- When the cement sets, cut a square of black felt to exactly fit inside the bottom of the case. This will soak up the excess alcohol used in the chamber and provide a good black contrasting background to view the tracks.
- Adding the felt to the lid is trickier. First, cut a square just large enough to completely cover the exposed glass on the inside of the top. Turn the top of the case upside down and drop the felt inside. Now comes the tricky part — fastening the fabric in place. You can't simply use glue, cement, or epoxy because alcohol eventually dissolves virtually every adhesive.
- A better solution is to pin the felt against the top using a wire screen. Cut the screen so that it is 2-3 cm (about 1") wider than the felt, and use a pair of pliers to bend down the four sides. Press the felt down, and then delicately staple the wire frame in place using ordinary office staples.
- Finally, to block out all of those track-destroying air currents, you need to seal all of the wood/glass joints with silicone. Run a bead of caulking along all of the joints inside and out, and then spread the silicone smooth with your finger. Let the silicone set up overnight before testing your chamber. That's it. You're done.

Step 3 — Enter the subatomic universe.



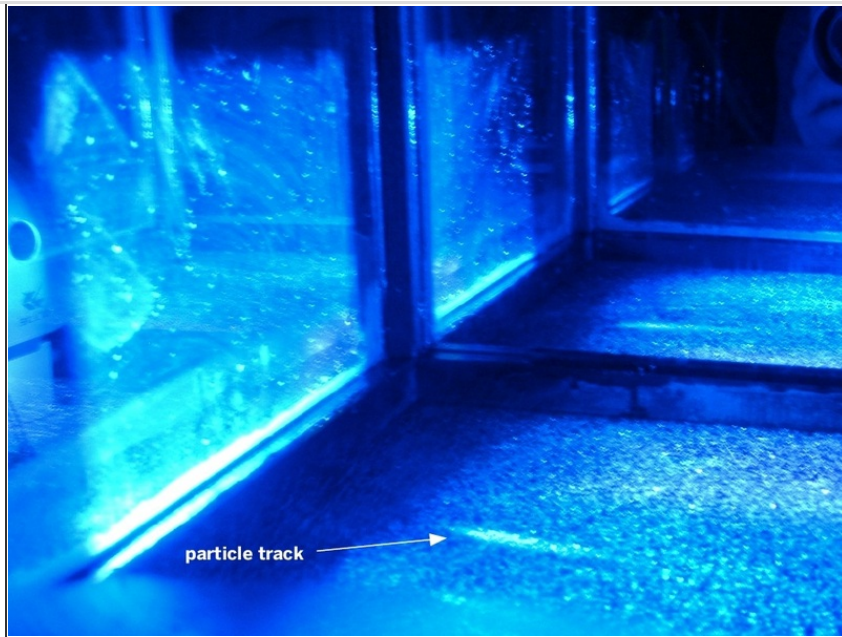
- Place the bottom of the chamber directly on top of a block of freshly cut dry ice. You want the entire bottom surface to come to the same temperature. (Any variation will cause air currents to flow inside the chamber and obliterate your tracks.) So if the chamber is larger than the block of dry ice, you'll need to create a tile of four blocks, and then center the chamber on that. As before, wrap exposed dry ice with a towel to prevent smoking.
- **NOTE:** If your supplier gives you irregular hunks of dry ice, you'll need to create a dry ice and alcohol bath. First, wrap the dry ice chunks in a towel and pulverize with a hammer. Next, dump the pulverized pieces into a plastic kitchen trash bag. Lay the bag on top of a doubled towel to provide insulation, and pour in several cups of isopropyl (rubbing) alcohol. (You'll waste less dry ice if you chill the alcohol in your freezer first.)
- Then wet the top of the bag with alcohol to provide a conductive seal, and press the bottom of the chamber onto the bag. This will chill the chamber nicely and avoids the mess and alcohol fumes of a traditional alcohol and dry ice bath.



- Next, fully charge the top pad of felt with alcohol and evenly moisten — do not saturate — the bottom pad. The alcohol on the bottom helps conduct heat out of the chamber and hastens the formation of the cloud. For this, you'll want the highest concentration of alcohol you can find. Go to your local auto supply store and purchase a bottle of Iso-Heet. This product is used to remove water from fuel lines and, as it turns out, is pure anhydrous isopropyl alcohol.
- Now close up the chamber and wait. It will take a while for all the dust in the air inside to settle out and for the temperatures of the different parts of the chamber to equalize. The show will start in about 20 minutes and it will go on for hours.
- To see it, turn out the room lights. Then shine a very bright column of light in from one side. A bright flashlight will work, but the batteries soon give out. I use the light from an LCD projector. The placement of the light is absolutely critical. The light must shine across the bottom of the chamber where the droplets are forming, and you must position your head low and at a steep angle relative to the light. Experiment a bit to find the positions that best illuminate the

chamber and provide the most spectacular viewing.

Step 4



- After the chamber has reached equilibrium, droplets will form very fast near the bottom and less so as you move up. The top of the cloud will be about 4cm above the bottom. That's where you want to focus your attention, where the wispy telltale tracks you are looking for will suddenly spring into being. Their appearance, like tiny ghosts dashing through a fog, is something out of Harry Potter.
- If you measure their rate and directions, you can learn a great deal. Consider adding a digital camera, shooting either through one side of the case, or through a hole cut in the felt and wire screen on the top. Take a steady march of images and keep only those that happen to capture a track. Long, straight, and slender tracks are most likely made by muons. Thick, stubby tracks that start and stop inside the chamber are created by alpha particles. Their rate will let you set an upper limit on large radioactive nuclei in your environment, like radon.
- Once you've astonished yourself, make plans to show your chamber to every person you possibly can. No demonstration I know is better able to get people excited about science than this one.

This project first appeared in [MAKE Volume 09](#), page 154.

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